

# PRODUCT DATA

## PULSE Source Path Contribution Type 7798 using Frequency, Order and Time Domain SPC Methods

*In today's competitive automotive industry, it is crucial to quickly and accurately evaluate the noise and vibration perceived by vehicle occupants. Based on customers' expectations, automotive engineers are taking NVH investigations (Noise, Vibration and Harshness) from concept and brand value definitions to actual design and development of the automobile.*

*The PULSE™ Source Path Contribution system, a multiple model management system, helps automotive engineers and managers improve the engineering decision process, and allows parallel evaluation of design alternatives and product variants throughout the vehicle development process.*



### Uses and Features

#### Uses

- Perform standard source path contribution analysis (transfer functions and operating conditions) for engine, powertrain or complete driveline assessment
- Combine vibro-acoustic path sensitivities and operating conditions to determine contributions
- Determine contributions in the frequency and order domains
- Contribution ranking
- Management of sources, paths and receivers in a structured model
- Management of large amounts of data (measurement, calculation and analysis) in a database
- 'What-if' scenario applications for target setting situations
- Evaluation of design alternatives and their effects to vehicle occupants
- Contribution analysis in conjunction with the Brüel & Kjær NVH Simulator
- Listen to and modify contributions

#### Features

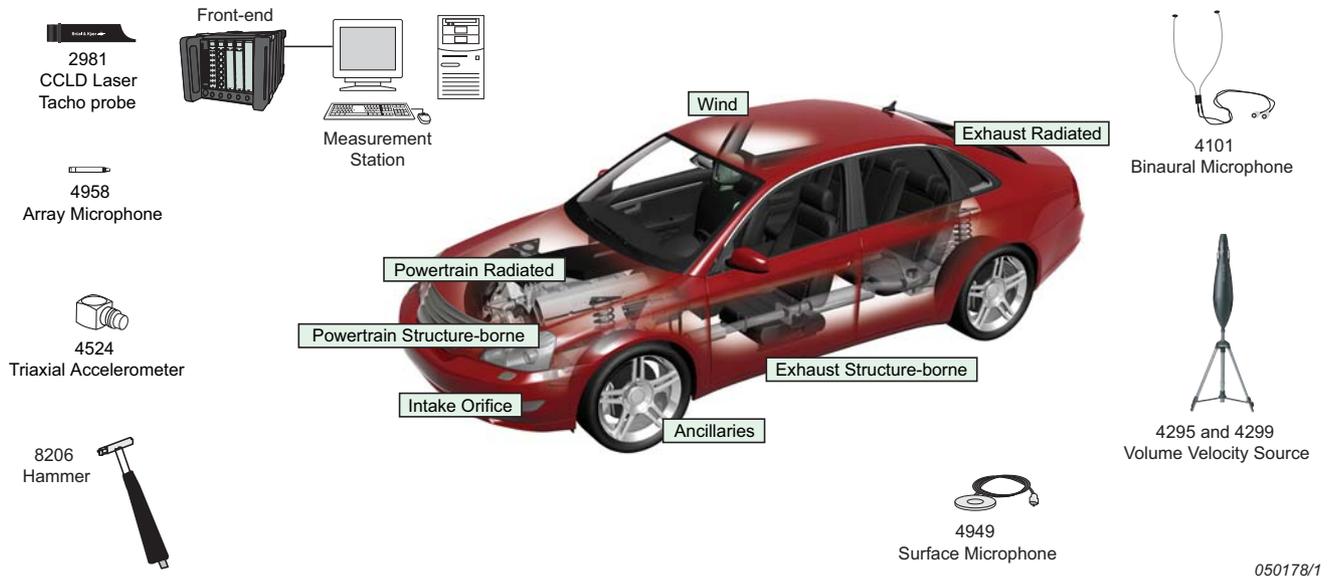
- Structure-borne contribution analysis (mount stiffness and impedance matrix)
- Source substitution methods (multi-reference technique for uncorrelated or partially correlated sources, like airborne sources)
- Multiple Coherence method (used, for example, for fast road noise investigations) with no need for transfer functions
- Time domain and frequency domain calculations for mount stiffness, impedance matrix and source-substitution methods
- Intuitive playback and analysis of Time Domain SPC results using SPC Time Insight module or NVH Desktop Simulator
- Source Path Receiver (SPR) model management
- Single interface for all task operations – model creation, data assignment, calculations and analysis
- Dedicated database for all SPC applications
- Use of UFF data in SPR model – target curves and test/CAE data
- Cascading tree structure for easy viewing and organisation, as well as optional table view
- Network-based data sharing
- Matrix Inversion Tool with robust inversion algorithms to determine forces when using the Impedance Matrix and Source Substitution methods
- Pre-configured SPC measurement templates for easy measurement process
- Export time data for post-analysis, such as order extraction with PULSE Reflex™ or PULSE LabShop

## Introduction

Source Path Contribution Type 7798 (SPC) helps NVH automotive engineers understand how noise and vibration are transmitted through various paths of the vehicle – both structure-borne and airborne. It provides a tool for optimising sound and vibration contributions according to engineering design parameters.

Brüel & Kjær offers complete SPC solutions, including transducers, instrumentation, signal processing platforms, SPC analysis software and training and engineering services for SPC.

**Fig. 1** Overview of the PULSE Source Path Contribution Type 7798 solution



### SPC Technique

The basis of the SPC technique is to perform a phased summation of partial responses from all noise and vibration paths to give total tactile and acoustic responses under specific operating loads at a given frequency or RPM. The system's design allows you to rate noise and vibration contributions using proven NVH analysis methods, such as the mount stiffness or the impedance matrix method for structure-generated phenomena, and the Source Substitution method for airborne phenomena.

Using SPC's Source Path Receiver model for vehicle test management, you maintain a coherent and manageable view of the vehicle throughout the NVH plan, and can intuitively organise operating and body characteristic information.

**Table 1** Signal types that can be assigned to each SPC method

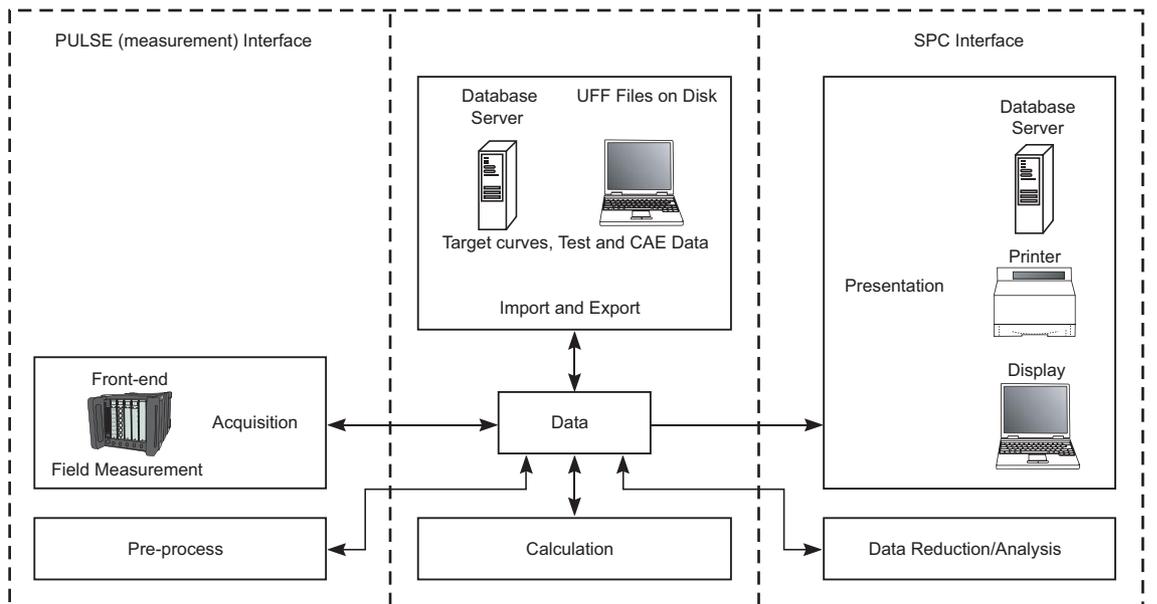
SPC Methods	PULSE SPC Viewer Type 7798-A + Following Module	Stationary Signals			Non-stationary (Run-up/ Run-down) Signals			Transient Signals		
		Frequency	Order	Time	Frequency	Order	Time	Frequency	Order	Time
<b>Impedance Matrix</b> (all sources correlated)	Type 7798-B or Type 7798-E	✓		✓*		✓	✓*			✓*
<b>Impedance Matrix with PCD</b> (multiple uncorrelated sources)	Type 7798-C	✓		✓*			✓*			✓*
<b>Mount Stiffness</b>	Type 7798-B or Type 7798-E	✓		✓		✓	✓			✓
<b>Multiple Coherence</b>	Type 7798-D	✓								

\* Principal Component Decomposition not performed. The Time Domain method implicitly allows multiple uncorrelated sources

## SPC Structure – All Modules

The data-centric architecture of the system allows you to measure with PULSE; save the data to a dedicated database; import UFF and synthesised CAE data saved on file; export post-processed data to the database; and, create and manage the Source Path Receiver (SPR) model throughout the test and analysis phases.

**Fig. 2**  
Data-centric architecture and application concept



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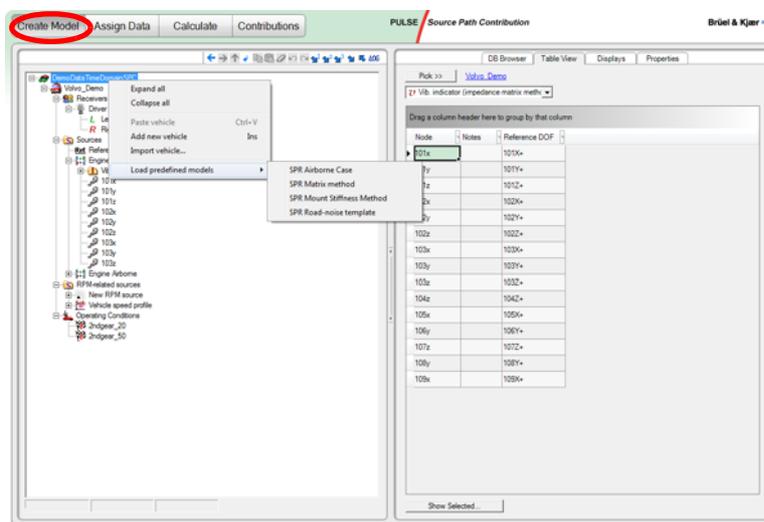
The SPC interface is built around this cascading Source Path Receiver model, which specifies all the sources, paths and receivers involved in the NVH test of a single vehicle or vehicle component.

Once you have decided which method you are using, the software guides you easily through the measurement/analysis process using the following tasks:

- Create Model
- Assign Data
- Calculate
- Contributions

### Create Model

**Fig. 3**  
The Create Model task focuses on the creation of an SPR model in cascading tree format



SPC's *Create Model* task allows you to define the SPR model, that is, how many receivers, how many sources and what type, how many paths, what method is used to estimate input strength to each path, operating conditions, tachometers, etc. The number of source, receiver and indicator points, the analysis method(s), type of data required, and relevant operating conditions are all determined by you as branches and nodes are added to the tree (an unlimited tree depth). Logical data grouping and insertion options, as well as property values of nodes based

on the customised SPC database, aid in model structuring. The task allows you to create, modify, save, load, import and export SPC models, as well as enter DOF information related to the various positions. Once defined, a model represents the target cascading process in the vehicle, and can be used throughout testing and analysis.

Information in the tree is also available in tabular format.

Several models can be created and/or viewed at any one time. Standard editing, expand and collapse tools via the SPC toolbar make it easy to compose, manage and navigate models as they are created.

Each model is saved to the SPC database located locally or on a network server, for viewing, sharing and further analysis at any stage of the NVH process.

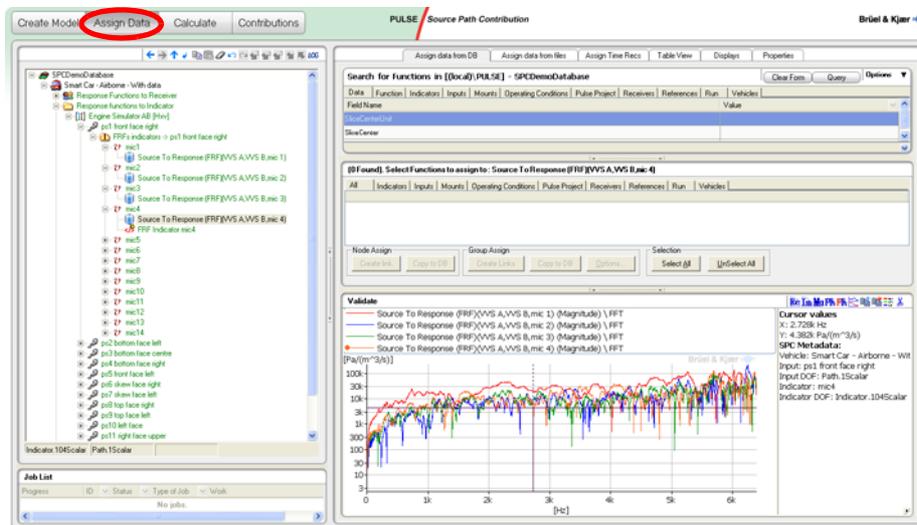
### Assign Data

The *Assign Data* task lets you extend the model with 'placeholders' (these are tree items to which measured data is to be assigned). Measured data (transfer and operating functions), CAE data and target curves stored in the database or saved as UFF files on disk, are located and assigned to the SPR model. The system automatically maps data to nodes according to DOF-based criteria set by you. Colour-coding is used to rapidly visualise the status of the model as it becomes populated with information.

Once a model has data assigned to it, a test operator can use the model to view the vehicle components' behaviour under test and begin to rank contributions to the overall noise level.

Fig. 4 shows a typical SPC display, with 'uff' browser and one FRF function loaded. FRF Spectra, or operating data, can also be displayed.

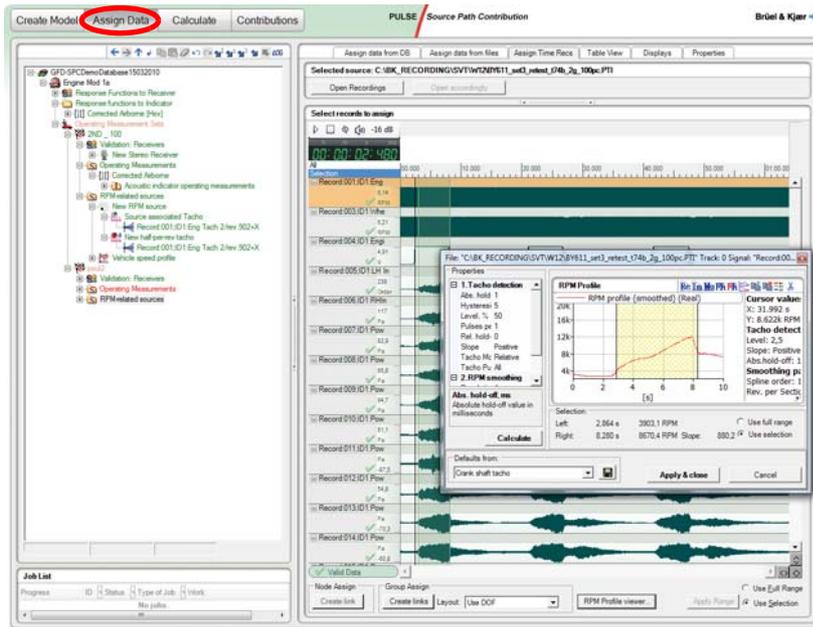
**Fig. 4**  
The *Assign Data* task. Using *Assign Data* from Database, stored spectrum data can be retrieved and inserted in the model. Once inserted, the text in the tree will change to green



Use the *Assign Time Recs* tab, when applicable, to assign the operational recordings (time series). You can open PULSE recordings (including .pti, .wav and .uff files) and show the contents graphically. You can also listen to recordings and zoom in and out on track(s). The selected channels can be manually or automatically assigned to the model. This can be either a full time series or selected time period, or RPM range.

A tool is included that facilitates time frame selection, based on engine RPM values. The tool estimates engine RPM profile (or vehicle speed profile) based on the selected tachometer channel, see Fig. 5.

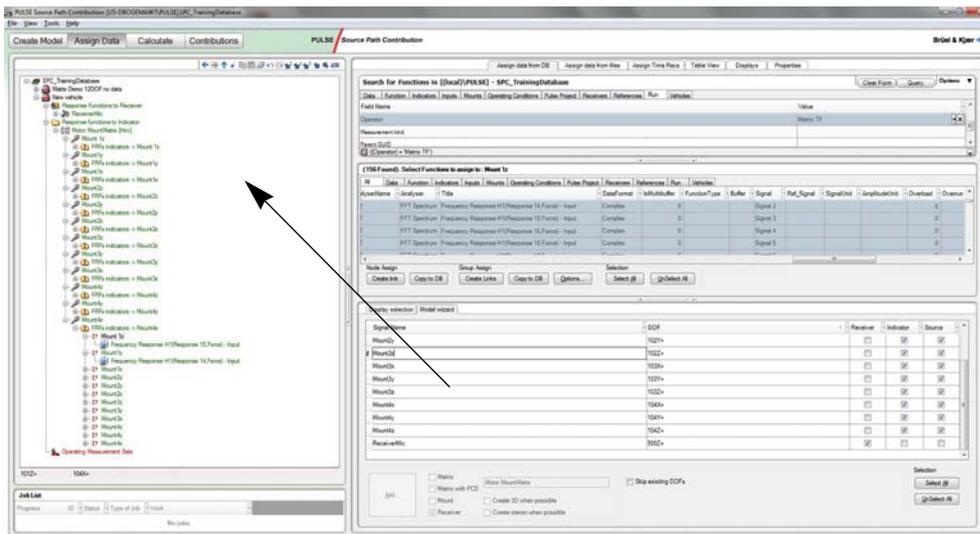
**Fig. 5**  
Time data and RPM tool in the Assign Data task



### Model Wizard

The *Model Wizard* tool makes it even easier and more streamlined to create an SPC model and assign data quickly. The tool automatically generates the SPC model (sources, paths, matrices, receivers, etc.) based on the data measured for the SPC model. Select the frequency response functions from the measurement, and the Model Wizard will enable you to create an SPC model based on the DOF information (point number and direction information). The data is assigned to the model at the moment of creation.

**Fig. 6**  
The Model Wizard makes creating an SPC model and assigning data fast and easy



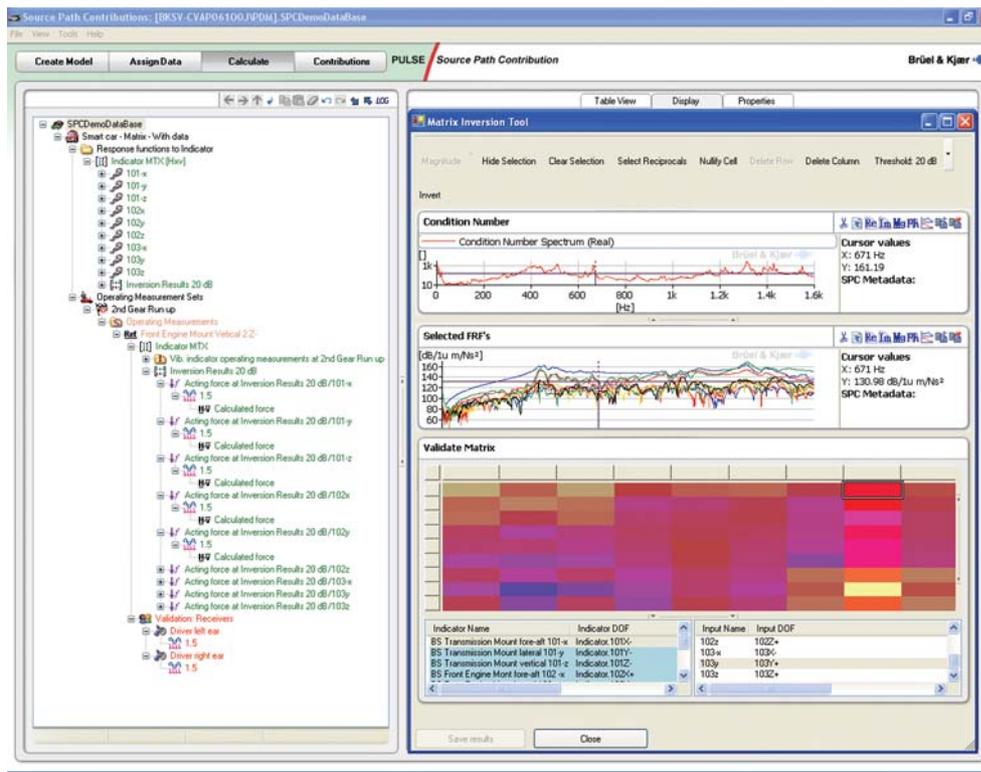
### Calculate

The *Calculate* task allows you perform maths operations, for example:

- When using the Mount Stiffness method, it may be necessary to validate and re-calculate data prior to contribution analysis
- With Impedance Matrix and Source Substitution methods, the forces/source strength are unknown and must be calculated in order to assess contributions. Using the integrated Matrix Inversion Tool, forces/source strengths are calculated by inverting a matrix of the measured FRFs (acceleration to force or pressure to volume velocity), see Fig. 7

As calculations are performed, the tree is extended by the new calculated items (for example, results of the matrix inverse or extracted orders). Additionally, the input source strengths are prepared and calculated, for example, estimated forces and acoustical point source strengths.

**Fig. 7**  
Calculation of data using SPC's Matrix Inversion Tool to view and edit the matrices before inversion



### Contribution

During contribution analysis, input contributions to overall vehicle interior noise or vibration are evaluated and compared to total or measured values and deviations from set targets can be identified. Modifications to the vehicle are done here, and reassessment of noise and vibration contributions easily performed.

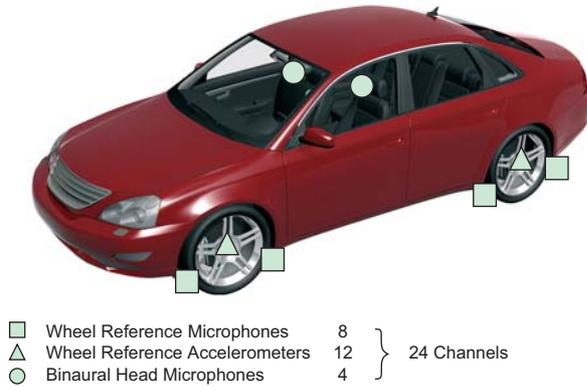
Results can be manipulated to account for different loads, operating conditions, or other parameters for benchmarking and determining vehicle design alternatives.

**Fig. 8**  
The Contribution Analysis task allows you to focus on all the noise contributions arriving at a defined receiver. Displays can give clear pictures of any deviations from set targets



## SPC Multiple Coherence Method

**Fig. 9**  
Typical measurement setup for road noise multiple coherence method



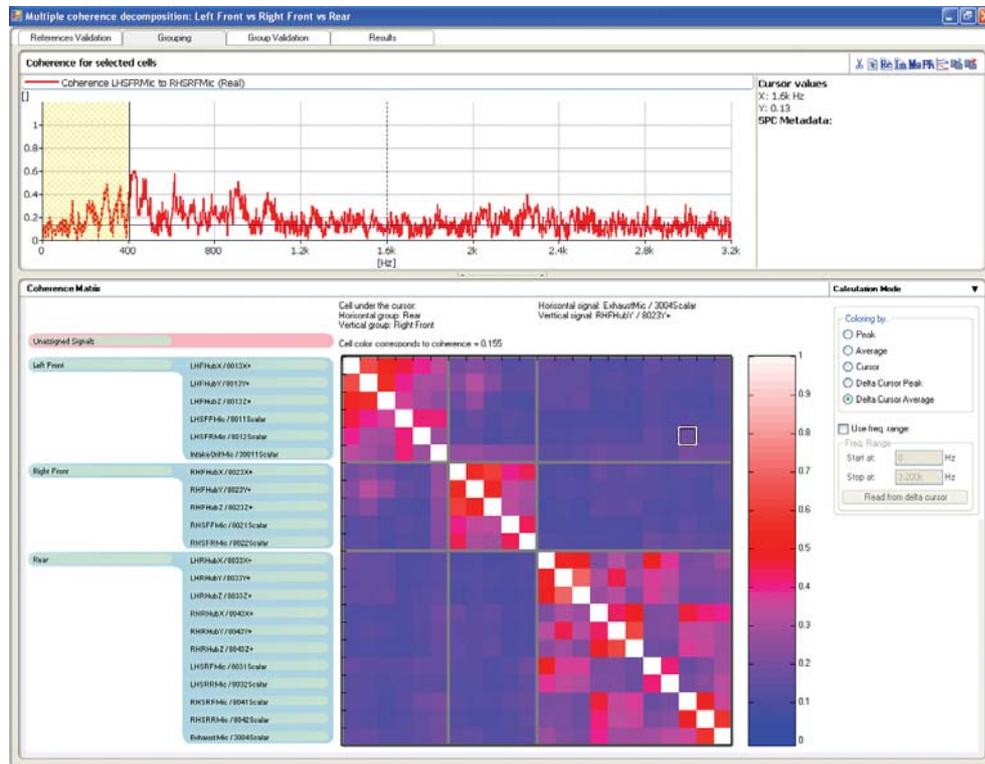
SPC Multiple Coherence Method Type 7798-D (SPC MC) allows the quick assessment of contributions from coherent sources in the vehicle. This module applies mostly to road noise problems in vehicles, since noise and vibration inputs from wheels can be partially correlated.

The SPC MC module allows you to group signals according to the data set available, and to assess contributions from these various groups (for example, front vs. rear, or front structure-borne vs. front airborne vs. rear structure-borne vs. rear airborne). In this technique, the

measurements can be done very quickly, since they do not require the measurement of transfer functions, only operating inputs.

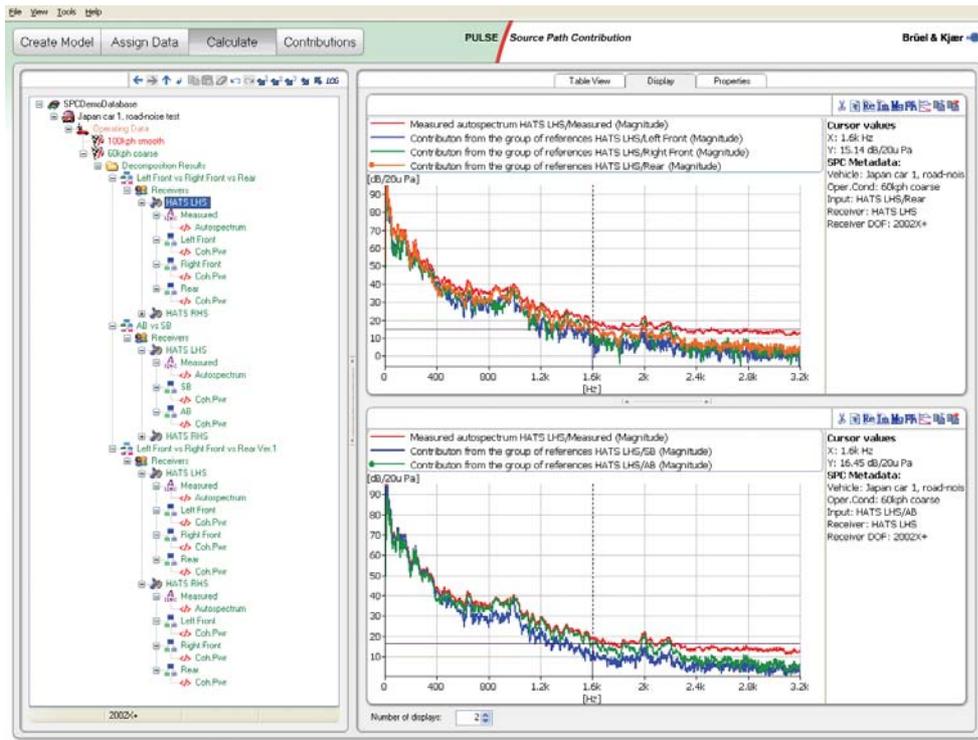
Prior to the calculations, you can create different signal groups and visually investigate the ordinary coherence between different groups (see Fig. 10). You can visualise the coherence for a specific frequency cursor value, peak, or for a frequency band average.

**Fig. 10**  
Ordinary coherence grouping method, the figure here shows left front vs. right front vs. rear groups



The results are presented in SPC where you can see how the measured autospectrum from the receivers are compared to the contributions from the different groups created (see Fig. 11).

**Fig. 11**  
Results displayed in SPC. The first plot shows the comparison of measured receiver autospectrum and contributions from left front, right front and rear groups. The second plot shows the contributions from another grouping procedure (structure-borne and airborne signals) compared to the measured receiver



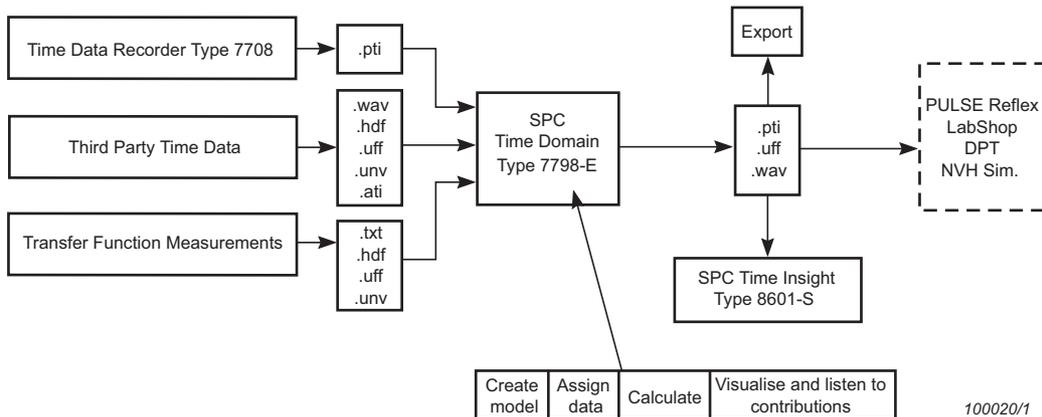
## Time Domain SPC

Time Domain SPC module helps engineers understand how noise and vibration are transmitted through various paths of the automobile – both structure-borne and airborne – while working in the time domain. It is used to calculate contributions, source strengths and forces in the time domain. This is particularly useful for analysing transient events and is also applicable to any signal type (transient, stationary or run-up/down).

The methods used in Time Domain SPC, namely the Matrix Inversion and Mount Stiffness methods, allow for source substitution, for example, replacing engine noise in an existing vehicle with an engine measured on a test rig. Contributions, source strengths and filters can be exported as .pti, .uff and .wav files with embedded tachometers. Type 7798-E can read various data formats, including .wav, .pti, .rec, .uff binary (LMS) and .hdf (HEAD).

To perform a Time Domain SPC analysis, the process begins with recording time data, processing in SPC using time domain techniques, basic playback an analysis within SPC, and export to SPC Time Insight, PULSE Reflex, the PULSE NVH Vehicle Simulator or other software for more in-depth analysis and playback. See the overview in Fig. 12.

**Fig. 12**  
Time Domain SPC overview



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## Method

Compared to frequency or order domain solutions, Time Domain SPC can be used for stationary, non-stationary and transient operating conditions/signals. Implicitly, the method allows analysis of uncorrelated sources in one, or several, impedance matrices. For convenience, the Mount Stiffness method is used to estimate forces in a quick and easy way.

Creating SPC models and assigning data is the same process for Time Domain SPC as it is for frequency domain processing. The only difference is that for operating data, time domain data is assigned instead of frequency domain data.

In the *Calculate* task, the Matrix Validation tool is used to facilitate matrix inversion and rapidly validate the inversion results. The tool enables you to manipulate the FRF matrix, change filter and inversion parameters, view effects of these changes, and rapidly listen to and evaluate in the time and frequency domain the results of the matrix inversion for each operating condition. The sum of all contributions is calculated and can be listened to back-to-back with the measured receiver data for validation. The spectral content is also available for comparison and validation. The spectra update in real-time as the sound is played, providing instant and intuitive feedback.

The summed contributions can be compared to recorded receiver signals and the calculated contributions, source strengths and transfer functions can be exported from Time Domain SPC to SPC Time Insight for further playback and analysis. They can also be exported to PULSE Reflex for further processing, or to a number of other post-processing data analysis programs.

**Fig. 13** Time Domain SPC Calculate and Contribution tasks. **Left:** The Matrix Inversion Tool validation step in the Calculate task. **Right:** Contribution List in the Contribution task where you select contributions, initiate show/listen view and export contributions



### SPC Time Insight Type 8601-S

SPC Time Insight is part of the Time Domain SPC system. It includes advanced playback, analysis, mixing and filtering tools and allows inspection of data in the time and frequency domains. It also enables back-to-back comparison of different model results. SPC Time Insight has the look and feel of the NVH Simulator, with an easy upgrade path to full Brüel & Kjær’s Desktop Simulator (DTS). For more information on Type 8601-S, see its product data ([BP 2340](#)).

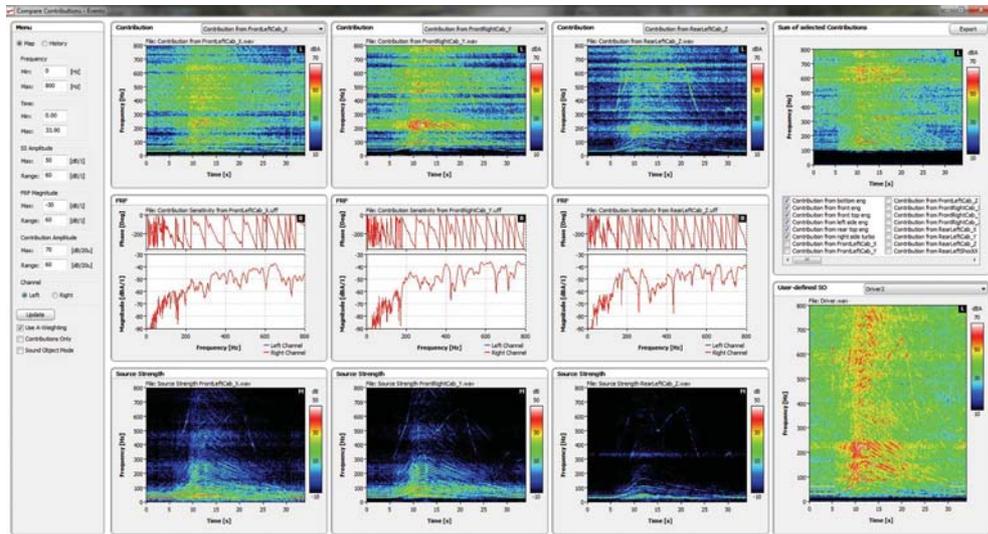
With SPC Time Insight Type 8601-S, the following options are also included:

- Contributions can be played simultaneously, in groups or individually (see Fig. 14)
- Multiple sets of contributions can be used for back-to-back comparison, for example, different vehicles, or different design alternatives. These datasets can be synchronised to various parameters, including time, RPM, speed (see Fig. 15)
- A range of data can be selected for playback, and can be looped to play continuously. This range can be selected using time, RPM, vehicle speed, or other parameters
- Filters can be saved/loaded, applied in real-time or off-line, and mixed together
- Displays can also work in real-time, or be used off-line with contribution spectra
- Type 8601-S can be easily upgraded to the full PULSE NVH Desktop Simulator Type 8601 (DTS) program
- SPC Time Insight projects can be used in the full DTS program, with the same functionality included in DTS as in SPC Time Insight

**Fig. 14**  
 Playback and real-time spectrum display in SPC Time Insight



**Fig. 15**  
 Source, path and contribution displays in SPC Time Insight



## Specifications – PULSE Source Path Contribution Type 7798

Source Path Contribution Type 7798 is NVH analysis software based on the PULSE Multi-analyzer System

### PC Configuration

#### REQUIRED PULSE SOFTWARE

For all SPC modules, you must have PULSE SPC Viewer Type 7798-A (this is the general base software) and at least one valid PULSE Data Manager Type 7767 license

#### RECOMMENDED PULSE SOFTWARE

- PULSE FFT & CPB Analysis Type 7700
- PULSE Time Data Recorder Type 7708
- PULSE Order Analysis Type 7702
- PULSE NVH Desktop Simulator Type 3644-A
- PULSE Reflex Base Type 8700 + any relevant PULSE Reflex application modules

#### RECOMMENDED PC CONFIGURATION

- 2.5 GHz Intel® Core™ i7 processor, or better
- 4 GB RAM, for Windows® 7 (x64) 8 GB RAM
- 160 GB Solid State Drive (SSD) with 20 GB free space
- DVD-RW drive
- 1 Gbit Ethernet network
- Integrated COM port or USB adaptor to COM (except with LAN-XI modules, which use a network connection)
- Microsoft® Windows® 7 SP1 (x32 and x64), Windows® XP Professional (SP 3)
- Microsoft® Office 2003 (SP 3), Office 2007 (SP 2) or Office 2010 (x32)
- Adobe® Reader® 10.1 (US version included with PULSE)

- Microsoft® SQL Server® 2008 R2 Express Edition (SP 1) (included with PULSE)
- Sound Board: 16-bit SB Pro-compatible 3D

### Software

#### ANALYSIS METHODS

- Mount Stiffness (structure-borne)
- Impedance Matrix (structure-borne)
- Source Substitution (multi-reference, for example, airborne)
- Multiple Coherence (for example, road noise)

#### USER INTERFACE

Task-driven user interface

#### Workflow Features:

- Data-centric architecture
- Six sample SPR models – two for each analysis method (one with sample data and one without)
- Integrated PULSE Data Manager tools: Retrieve from/save to database, calculator, new database creation and maintenance
- Pre-configured SPC measurement project templates via Project Launcher

**Display Functionality:** Advanced graphic tools

#### DATABASE

**Database Type:** Microsoft® SQL Server®

**Search Options:** Searches on all meta-data fields via user-defined SQL queries or browser-based plain text queries

**Capacity:** Database/hardware dependent

## Ordering Information

### Type 7798-A-X\* PULSE SPC Viewer

with at least one of the following:

- Type 7798-B-X\* PULSE SPC Mount Stiffness and Matrix Methods
- Type 7798-C-X\* PULSE SPC Matrix Method with PCD
- Type 7798-D-X\* PULSE SPC Multiple Coherence Method
- Type 7798-E-X\* SPC Time Domain (Matrix and Mount Stiffness Methods)
- Type 8601-S-X\* SPC Time Insight (requires Type 7798-E)

#### ACCESSORIES

- Type 3099-A-X\* PULSE LAN-XI and IDA<sup>e</sup>/IDA Multiple Module Front-end Driver
- Type 3099-A-X1\* PULSE LAN-XI Single Module and IDA<sup>e</sup>/IDA Systems any size Front-end Driver
- Type 3099-A-X2\* PULSE LAN-XI Dual Module and IDA<sup>e</sup>/IDA Systems any size Front-end Driver
- Type 3099-D-X\* PULSE VXI Multiple Module Front-end Driver

#### REQUIRED SOFTWARE

One of the following:

- Type 7767-A-X\* PULSE Data Manager, Single-user License
- Type 7767-B-X\* PULSE Data Manager, 5-user License
- Type 7767-C-X\* PULSE Data Manager, 10-user License

\* Where X = license model either N for node-locked or F for floating and y = optional channel count, from 1 (single) to 7. No number denotes unlimited channels (channel-independent)

### OPTIONAL SOFTWARE AND SYSTEMS

- Type 3644-A NVH Desktop Simulator
- Type 7700-Xy\* PULSE FFT & CPB Analysis
- Type 7708-X\* PULSE Time Data Recorder
- Type 7702-Xy\* PULSE Order Analysis
- Type 7753-X\* PULSE Modal Test Consultant
- Type 7765-X\* PULSE Operating Deflection Shapes Test Consultant
- Type 7784-X\* PULSE Volume Velocity Source Measurement
- Type 8700-X\* PULSE Reflex Base

#### SOFTWARE MAINTENANCE AND SUPPORT

- M1-3099-A-X\* Software Maintenance and Support Agreement for PULSE LAN-XI and IDA<sup>e</sup>/IDA Multiple Module Front-end Driver
- M1-3099-A-X1\* Software Maintenance and Support Agreement for PULSE LAN-XI Single Module and IDA<sup>e</sup>/IDA Systems Any Size Front-end Driver
- M1-3099-A-X2\* Software Maintenance and Support Agreement for PULSE LAN-XI Dual Module and IDA<sup>e</sup>/IDA Systems Any Size Front-end Driver
- M1-7798-Z<sup>†</sup>-X\* Software Maintenance and Support Agreement for Type 7798-Z-X\*
- M1-8601-S-X\* Software Maintenance and Support Agreement for SPC Time Insight

† For Types 7798, Z = A, B, C, D and E

## Typical System Configurations

Type	Description	Engine Structure-borne and Airborne Assessment	Easy Road Noise Assessment
		18-ch. PULSE System	24-ch. PULSE System
		<b>Quantity</b>	
Type 7798-A	PULSE SPC Viewer	1	1
Type 7798-B	PULSE SPC Mount Stiffness and Matrix Methods	1	
Type 7798-C	PULSE SPC Matrix Method with PCD	1	
Type 7798-D	PULSE SPC Multiple Coherence Method		1
Type 7798-E	PULSE Time Domain SPC	1	
Type 3660-C	5-Module LAN-XI Front-end Frame	1	1
Type 3053-B-120	12-ch. Input Module LAN-XI 25.6 kHz (CCLD, V)	1	2
Type 3050-A-060	6-ch. Input Module LAN-XI 51.2 kHz (Mic, CCLD, V)	1	
Type 7700-N	PULSE FFT & CPB Analysis	1	1
Type 7702-N	PULSE Order Analysis	1	
Type 7767	PULSE Data Manager	1	1
Type 3099-A-N	PULSE LAN-XI and IDA <sup>®</sup> /IDA Multiple Module Front-end Driver		
<b>Optional</b>			
Type 7753	PULSE Modal Test Consultant™	1	
Type 7765	PULSE ODS Test Consultant	1	
Type 7708	PULSE Time Data Recorder	1	1
Type 7784	PULSE Volume Velocity Measurement	1	
<b>Accessories</b>			
Type 4100-D	Sound Quality Head and Torso Simulator (HATS)		
Type 4101-A	Binaural Microphone (with TEDS)		
Type 4295	OmniSource™ Sound Source		
Type 4299	Volume Velocity Adaptor		
Type 4524	Triaxial Piezoelectric Accelerometer		
Type 4525	Triaxial Accelerometer		
Type 4948	Automotive Surface Microphone		
Type 4958	20 kHz Precision Array Microphone		
Type 7789	PULSE Time File Management		
Type 8206	Impact Hammer		
DB-3996	Head Extender (40 grams) for Impact Hammer Type 8206		
Type 2981-A	CCLD Laser Tacho Probe with Adaptor and High-temperature Fiber		
WA-1647	Car Seat Fixture		

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